

Preparing for Long Duration Space Missions



Dr. Marc Shepanek
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Disclaimer

This presentation represents the opinions of the author and not the policy or perspective of any portion of the federal government.

Qualifications

- Lead Aerospace and Behavioral Health NASA HQ
- Assistant Professor of Psychiatry Uniformed Services University of the Health Sciences
- US Representative in Human Biology and Medicine to the Scientific Committee on Antarctic Research (SCAR)
- NSF Grantee and Investigator on physiological and psychological adaptation to Antarctic Environment
- Cancer survivor with experience in severe weight and muscle loss, exposure to radiation
- Clinical practice at Washington Hospital Center.

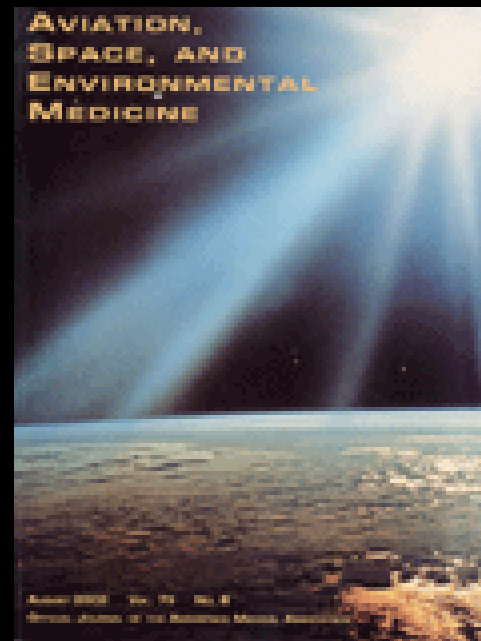


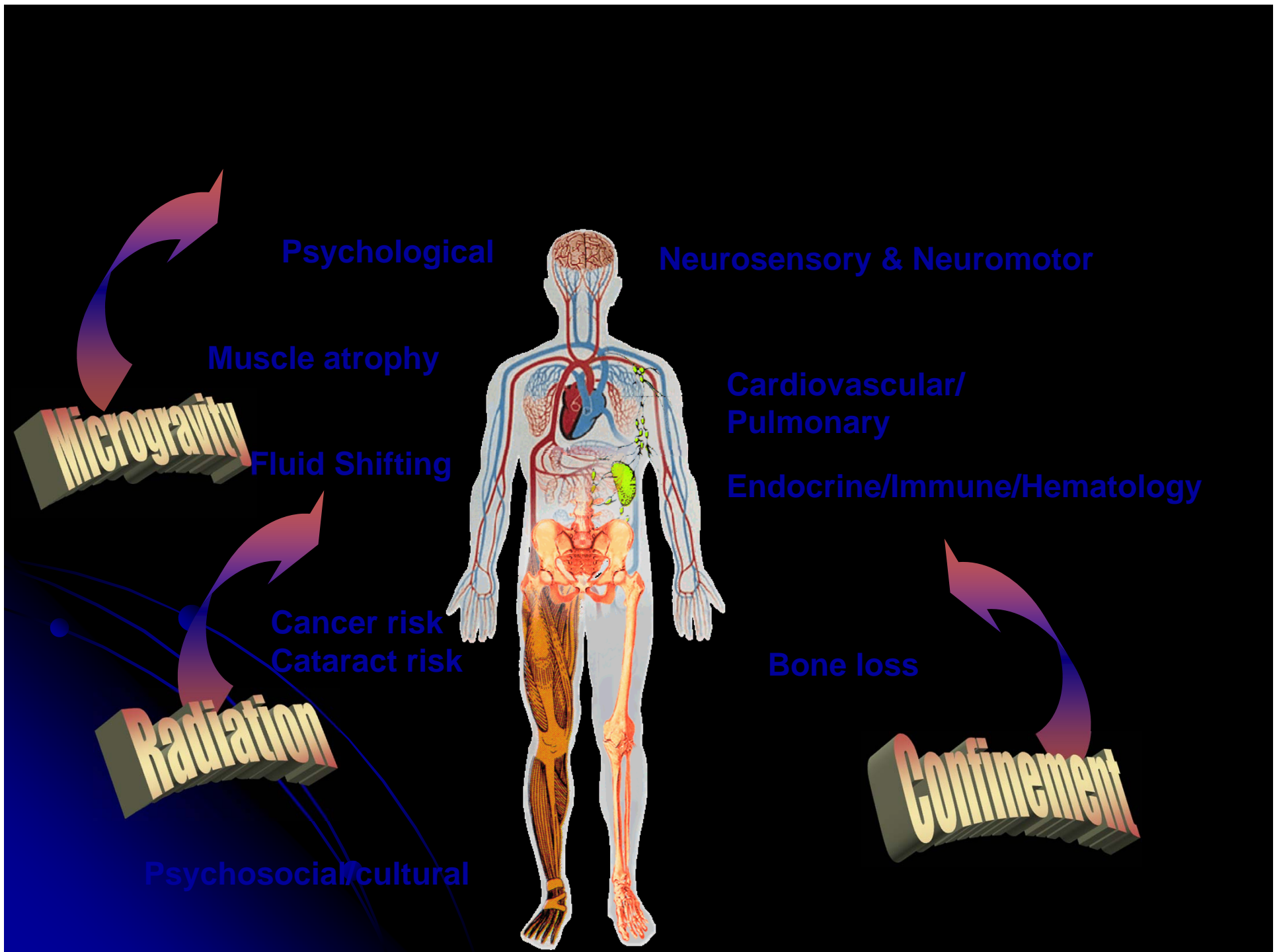
Plymouth England



Aerospace Medicine

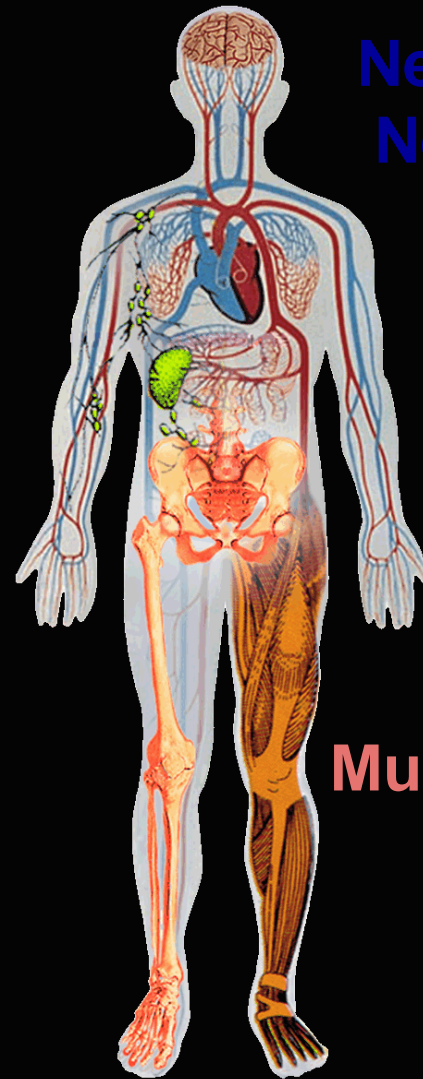
- Aerospace Medicine is that specialty area of medicine concerned with the determination and maintenance of the health, safety, and performance of those who fly in the air or in space





Adaptation

■ Adaptive
■ Pathological



Neurosensory &
Neuromotor

Cardiovascular/
Pulmonary

Endocrine

Psychological

Musculoskeletal

Radiation

Confinement

Conditions Managed in Extreme Environments

Mental and Behavioral

- Acute anxiety
- Depression
- Paranoid schizophrenia
- Gestures of suicide
- Anorexia nervosa (male)

Neoplasms

- Ca breast
- Ca testis
- SCC (branchial cyst)
- BCC
- Melanoma

Eye

- Retinal detachment
- Foreign object injury

Endocrine, nutritional, metabolic

- Gout

Genito - Urinary

- Renal Calculus
- Prostatitis
- Hydronephrosis
- STD

Poisoning

- Nutmeg toxicity
- CO poisoning
- Sick Building syndrome

Digestive

- Appendicitis
- Peptic ulcer
- Cholelithiasis
- Proctitis
- Leiomyoma eroding gastric vessel
- Dental

Infections

- Chicken Pox
- Herpes
- Hepatitis
- Polio - like illness
- Malaria
- Amoebiasis
- Giardia
- PUO

Respiratory

- Staph
- Pneumonia

Circulatory

- Cardiac arrhythmias
- Myocardial infarction
- Intracranial bleeding
- Brain
- Intracranial Pressure
- Strokes
- Unconscious

Some stresses experienced in space flight

- Space sickness
- Illness of family member
- Injury of family member
- Loss of income
- Loss of relationship
- Death of family member
- Dissolution of sponsoring institution
- Exhaustion
- Problems sleeping
- Eye injury
- Weight loss (muscle and bone)
- Fire
- Declining work schedule
- Gastrointestinal stress
- Vision problems
- Severe headache
- Loss of motivation

Evolution of Space Related Knowledge

Is There
A Problem?

Defining
the Problem

Countermeasures employed



1960

Facing the
unknown

1970

Extended flight
International
Intercultural

1980

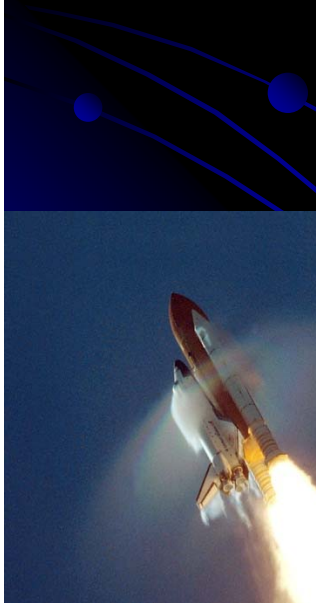
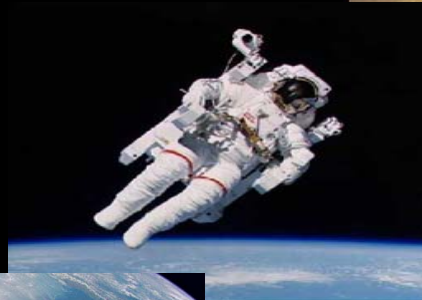
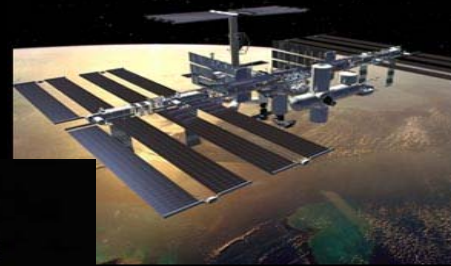
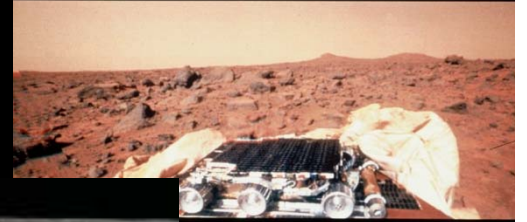
New vehicle
New Mission
configurations

1990

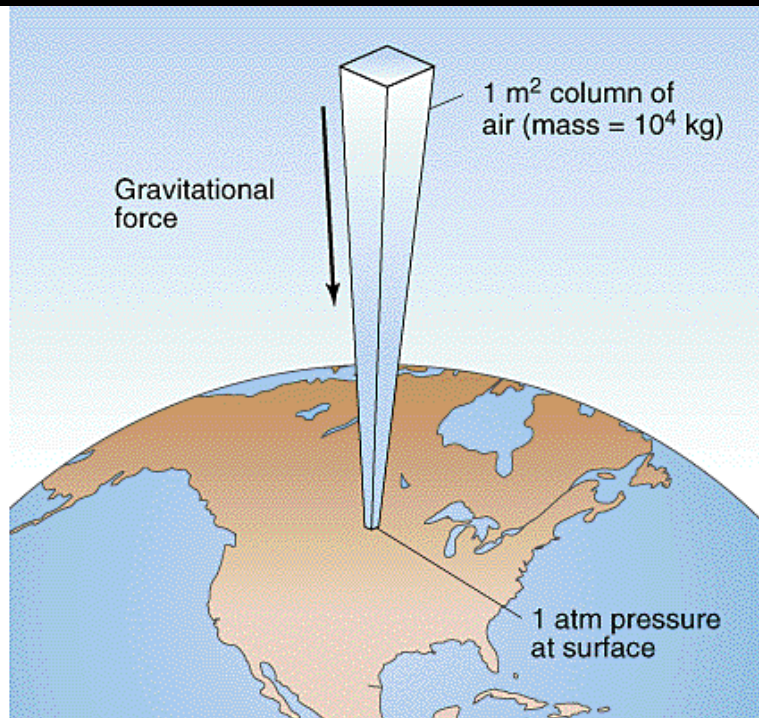
Integrating
International
Effort
Long Duration

2000

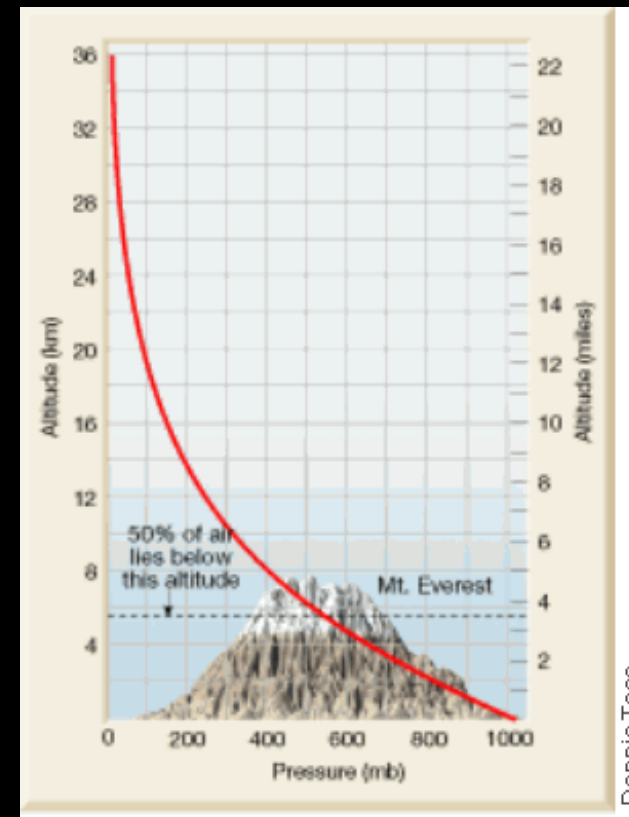
ISS and beyond



- The physiologic environment changes the moment you leave the surface of the earth

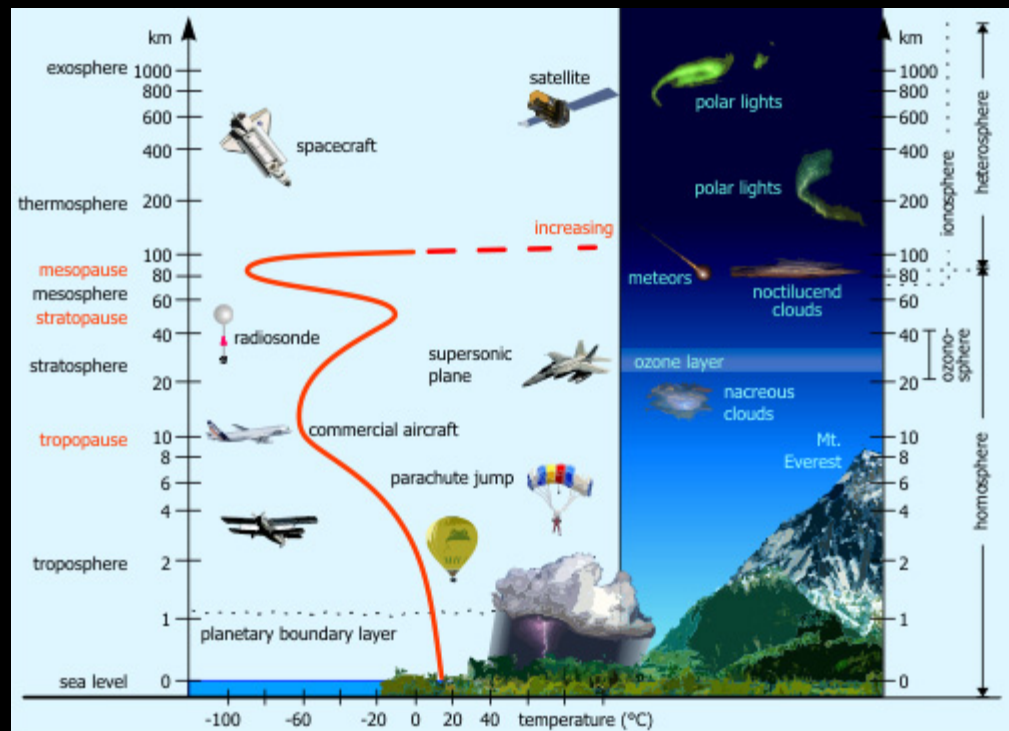
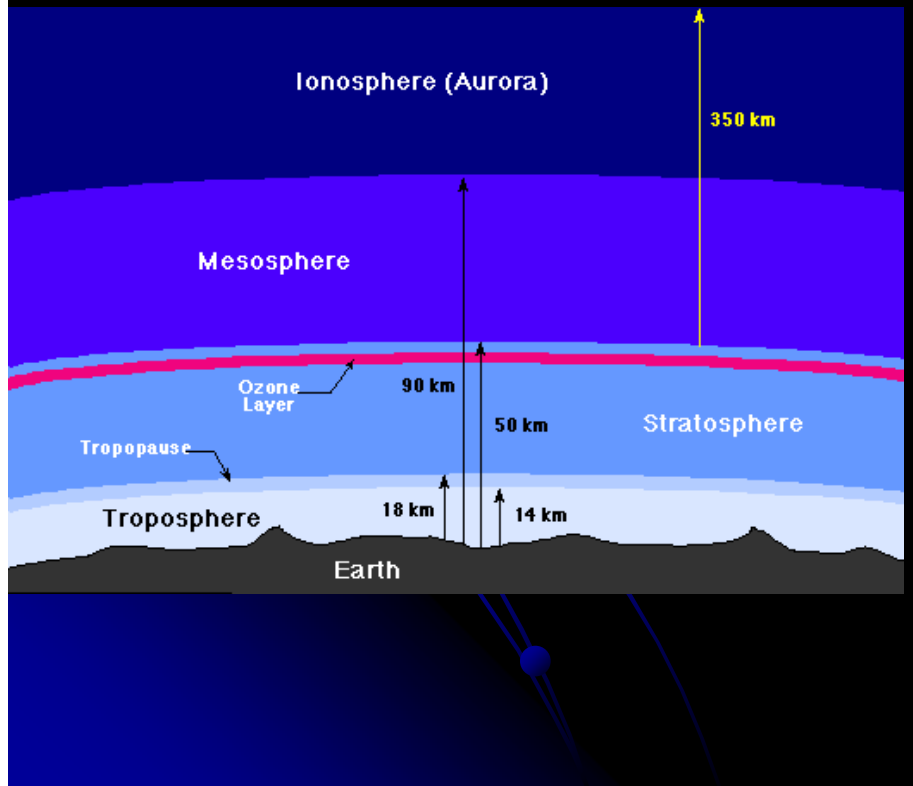


14.69 lbs/in² at Sea Level



Lots of Changes

- What are the human implications of altitude?
 - Pressure decreases
 - Gravity decreases
 - Oxygen availability decreases
 - Temperature decreases, then increases, then decreases, then increases again

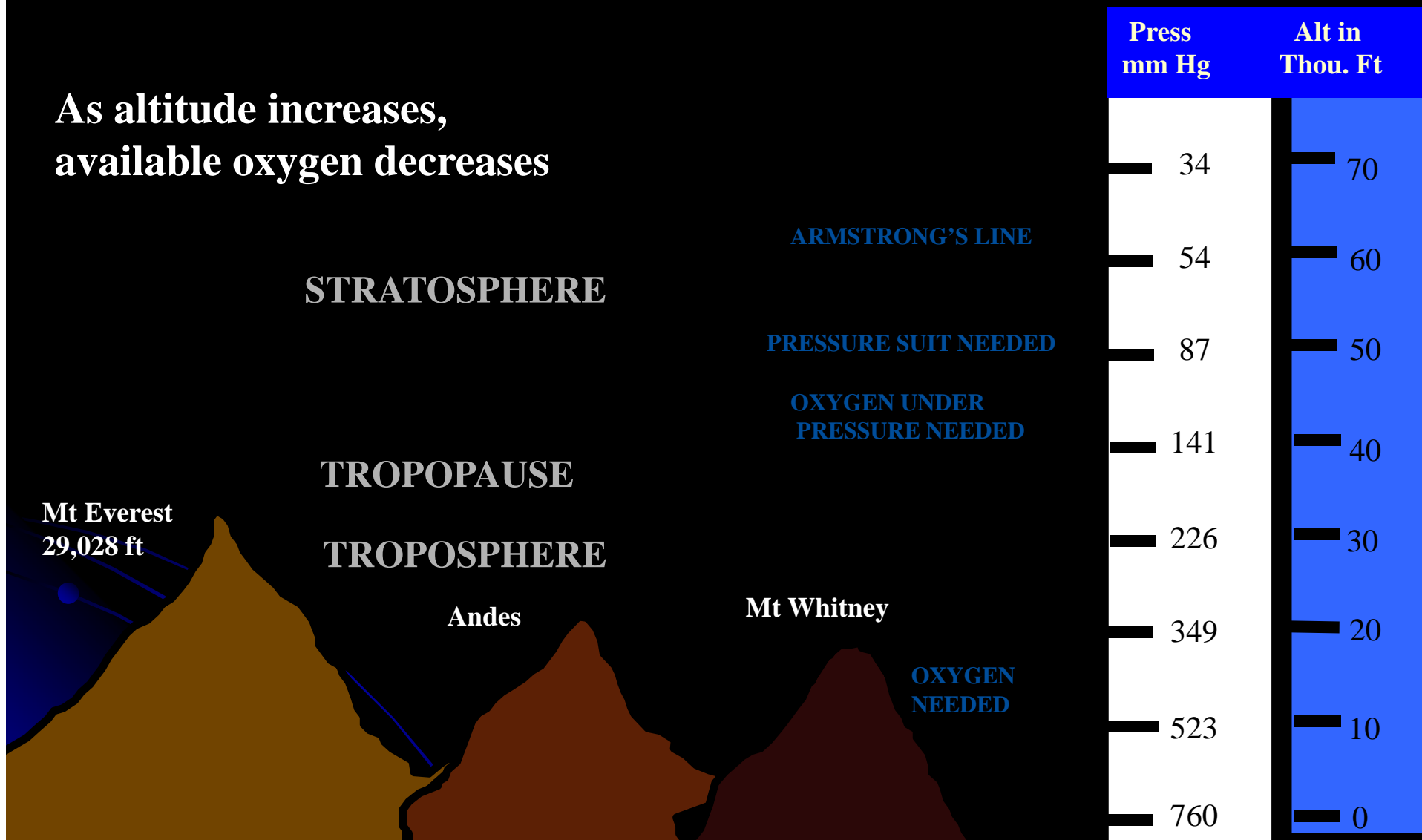


Potential Physiologic Effects of Space Travel

- Hypoxia
- Decompression Sickness
- Trapped Gas
- Acceleration
- Spatial Disorientation
- Visual Illusions
- Somato-sensory Illusions
- Human Factors
- Many others...

Environmental Requirements Oxygen

**As altitude increases,
available oxygen decreases**



Highest Human Habitation...18,000 ft

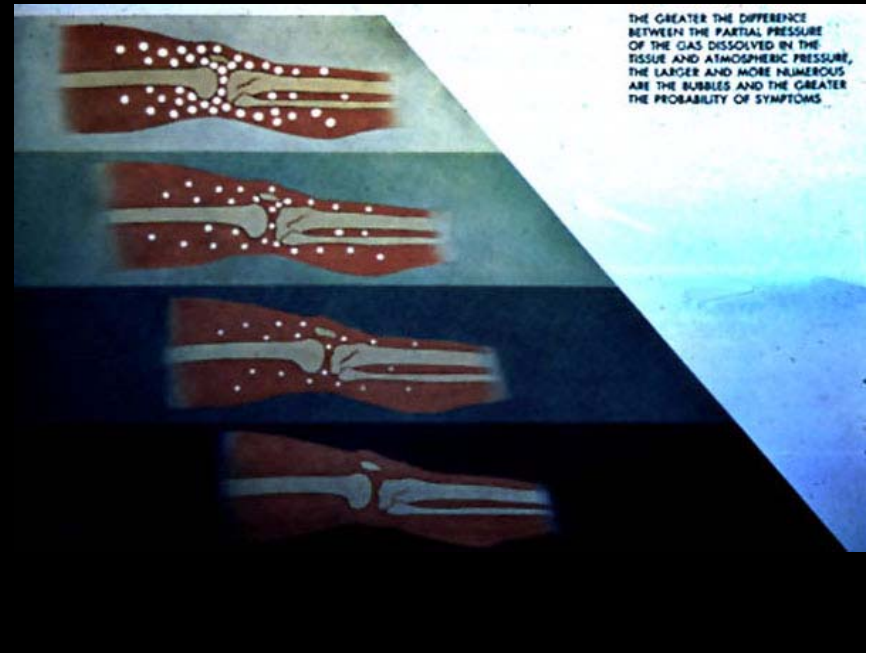
Hypoxia

- Subjective symptoms
 - Breathlessness, apprehension, headache, dizziness, fatigue, nausea, blurred vision, tunnel vision, numbness, tingling
- Objective signs
 - Increased respiratory depth and rate, cyanosis, confusion, poor judgment, behavioral changes, loss of coordination, somnolence, unconsciousness
- Effective Performance Time
 - 18000 ft – 20 to 30 minutes
 - 25000 ft – 3 to 5 minutes
 - 30000 ft – 1 to 2 minutes
 - 35000 ft – 0.5 to 1 minute
 - 40000 ft – 15 to 20 seconds
 - 43000 ft – 9 to 12 seconds



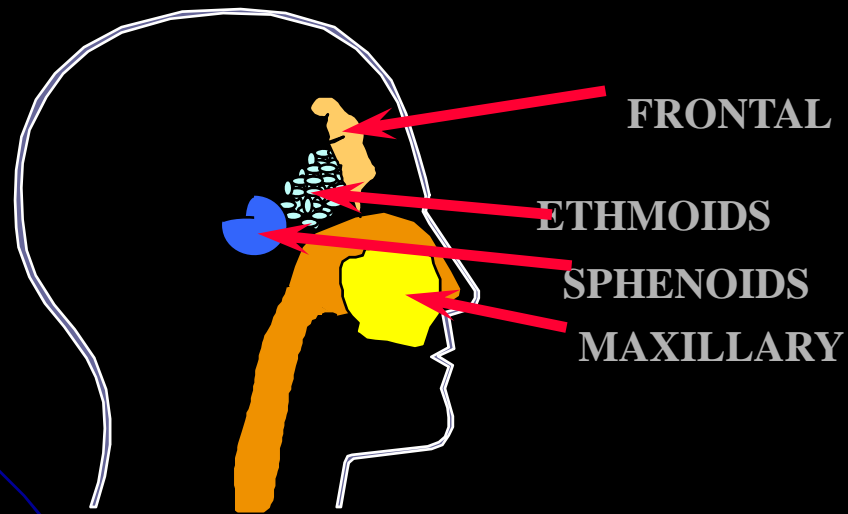
Decompression Sickness

- Bends
 - Pain only, 60 – 70% of cases
 - Skin bends
- Chokes
 - Multiple pulmonary gas emboli
 - < 2% of DCS cases
 - Dyspnea, substernal chest pain, dry cough
- Neurologic DCS
 - Spinal cord DCS
 - Brain DCS

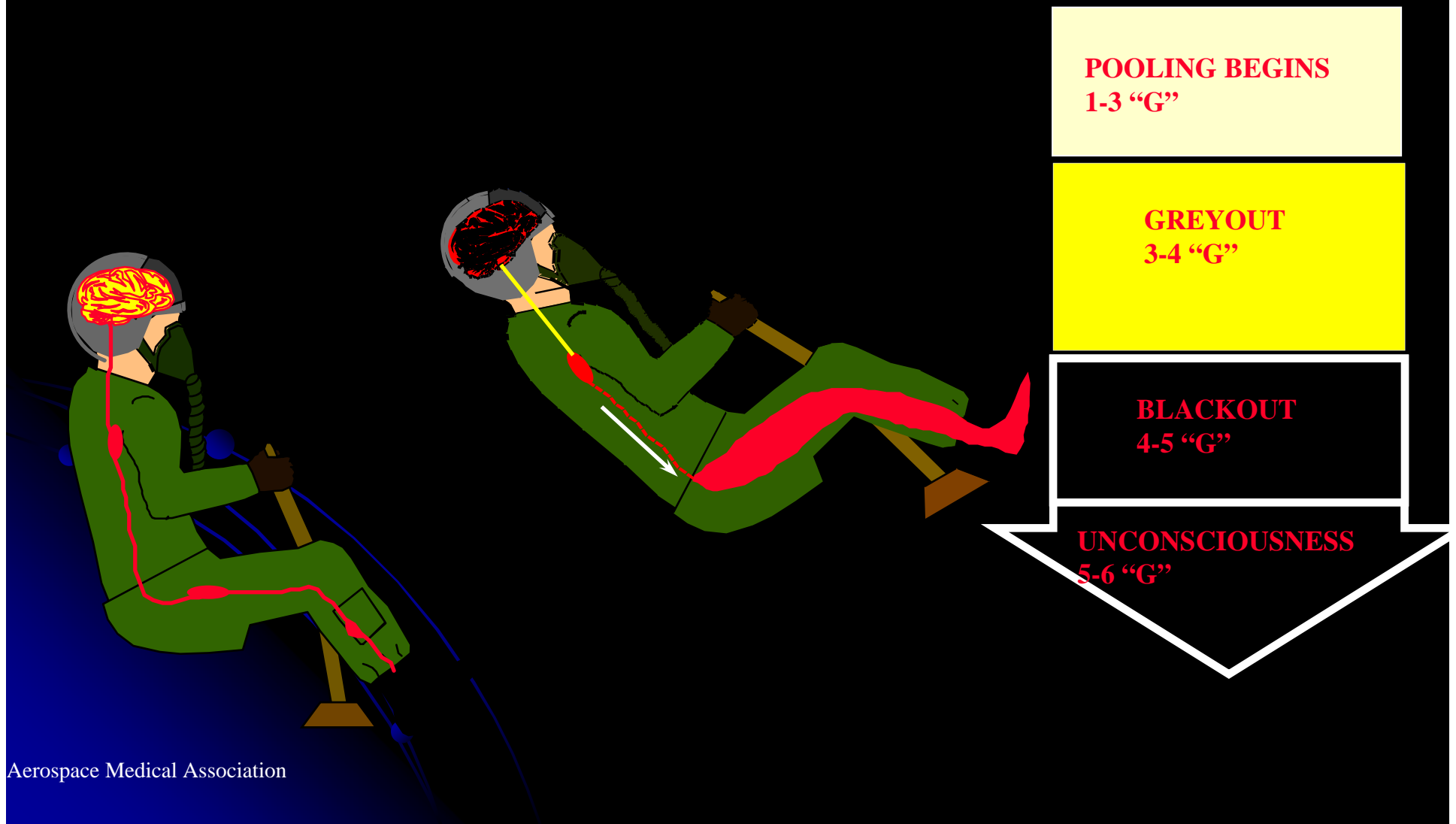


Trapped Air

There are several places in the human body where air can get trapped. The ear, the sinuses, and the stomach and intestines are a few examples.



Sustained Positive (+) Gz



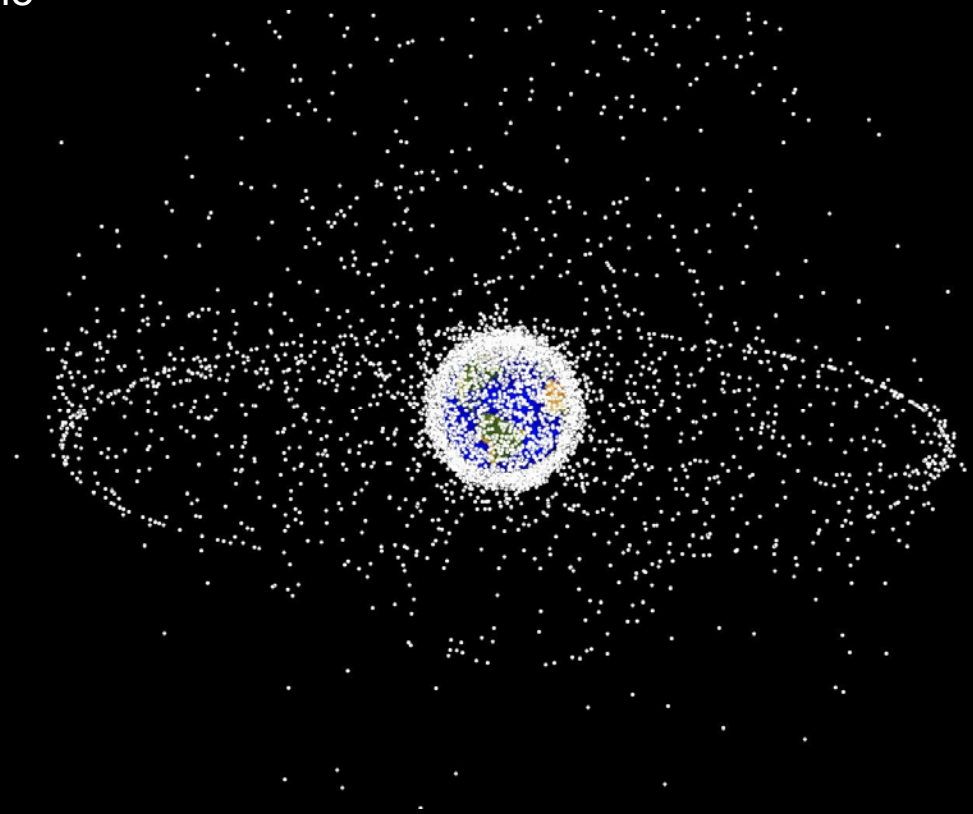
What's the big deal

- Huge consequences, in flight
- There isn't always a curb to pull over too

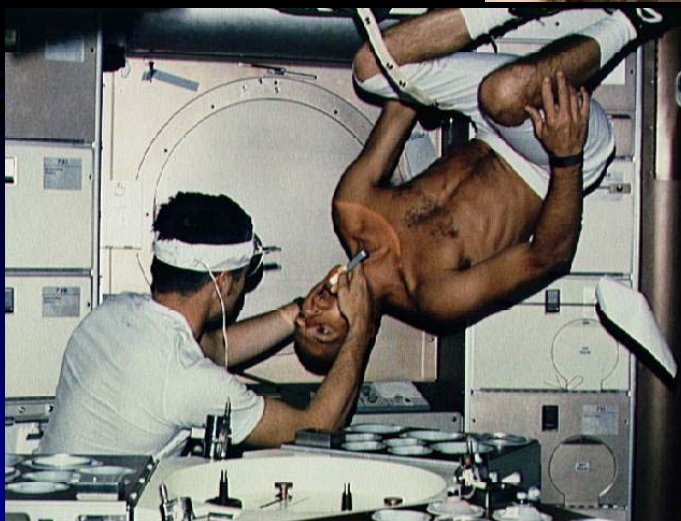


Challenges to Humans of Space Travel

- No Air, different mixes of gases
- Different Gravity, variable gravity
- Really High Speeds and deceleration
- Really Long Distances, really long time
- Too much Radiation, small and large
- Isolation and confinement as
Individuals, pairs and groups....

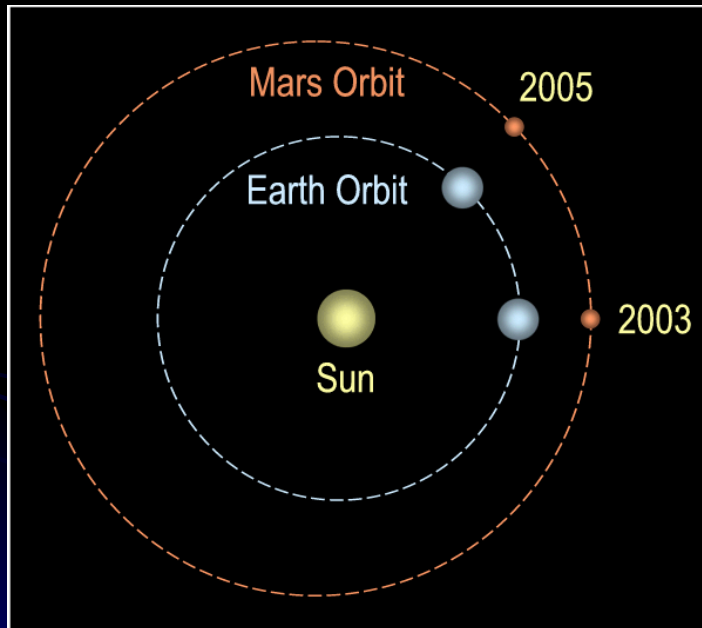


Weightlessness



Long Distances = Long Duration

The average distance from the Earth to the Moon is 238,854 miles



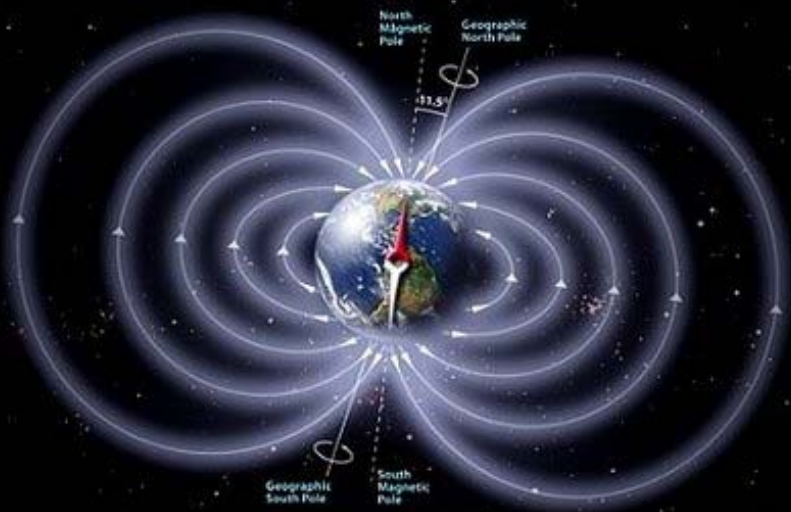
The average distance from Mars to the Earth is about 142 million miles, with a range of 56 to 401 million miles



Voyager 1, 1977
35,000 miles/hour
119 AU/ 11+ Billion miles away

Radiation Protection We Take For Granted...

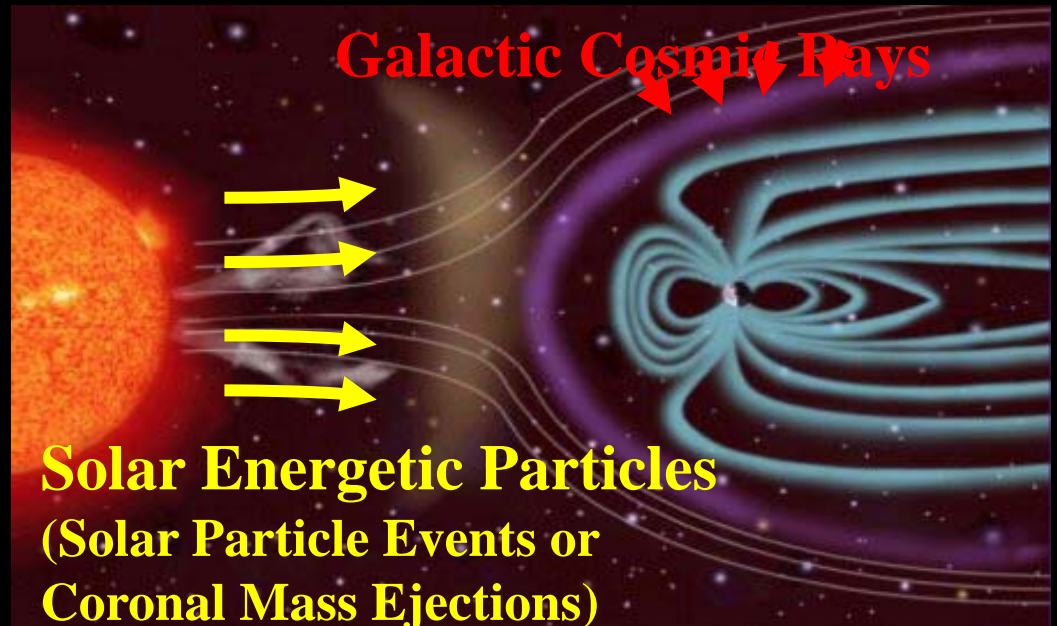
The Earth's Magnetic Field



Peter Reid (SCF-FUNL, 2003)

Galactic Cosmic Rays

**Solar Energetic Particles
(Solar Particle Events or
Coronal Mass Ejections)**



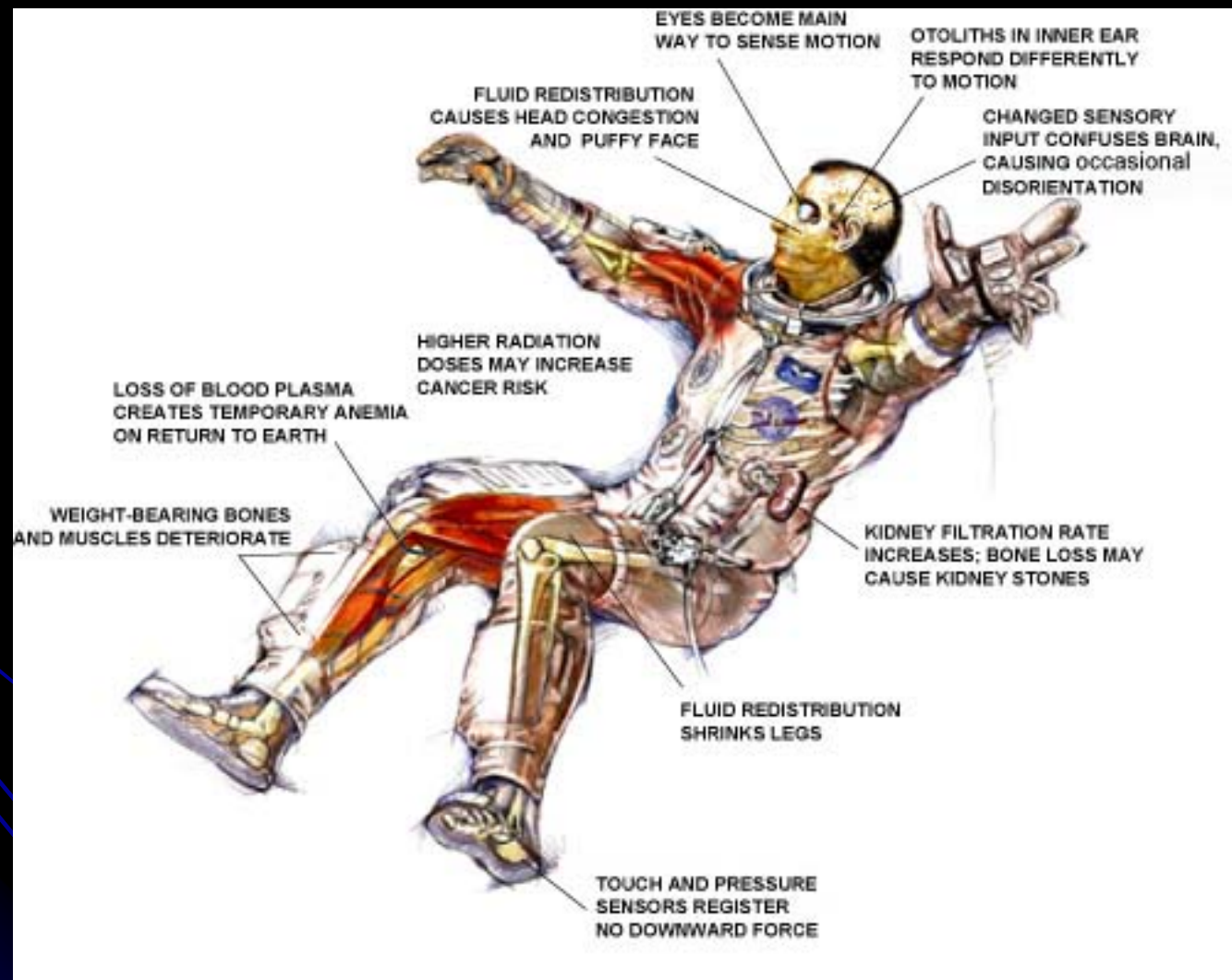
Isolation and Confinement with the same people...



Eating and Drinking in Space



Space Physiology



Current Top 3 Human Health Risks in Space Flight

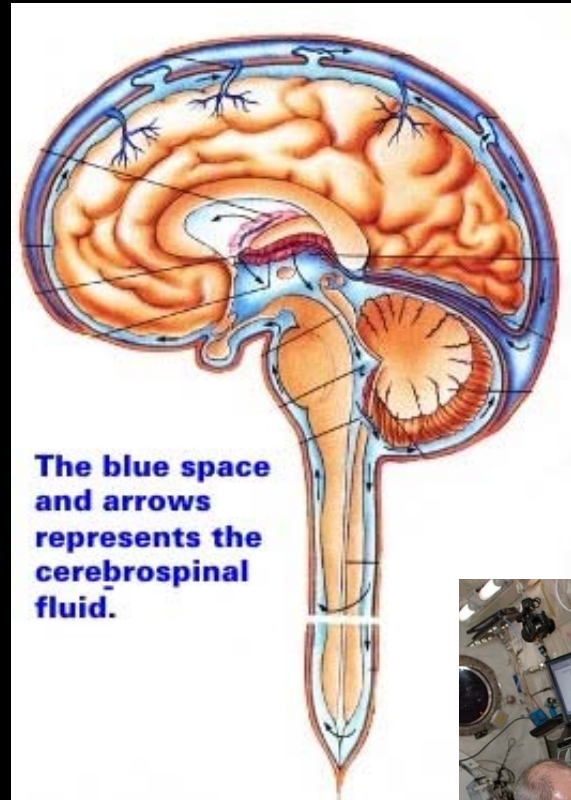
- Increased Intracranial Pressure
- Bone Loss
- Radiation Exposure



Risk vs Cost of Mitigation

Intracranial Pressure (ICP)

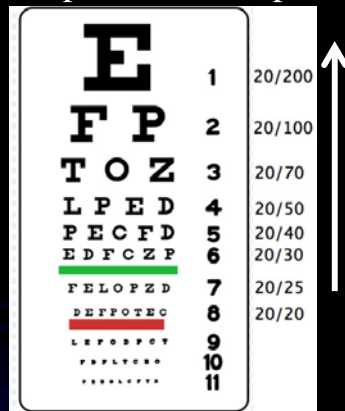
- This risk was “recently” found
 - First case noted in 2008
- Visual degradation and increased cerebral spinal fluid pressure found after “long duration” space flight
- Symptoms include visual disturbances after long duration space flight
- Postulated causes: microgravity fluid shift or physiologic response to increased CO₂ levels
- New assessments and research initiated



Visual Impairment/Intracranial Pressure

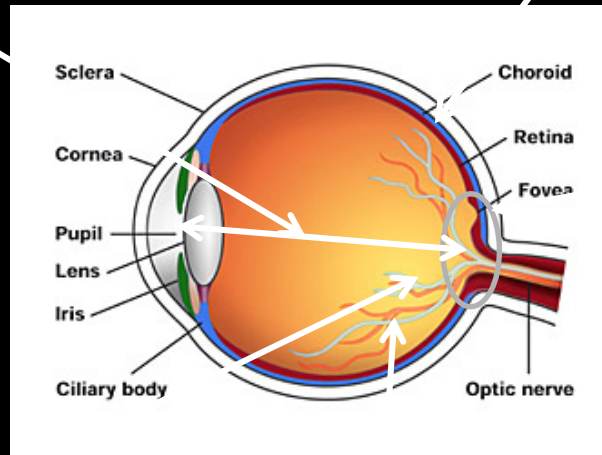
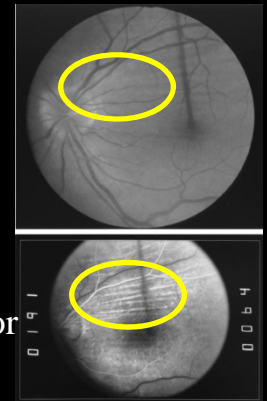
•Hyperopic Shifts

-Up to +1.75 diopters



•Choroidal Folds

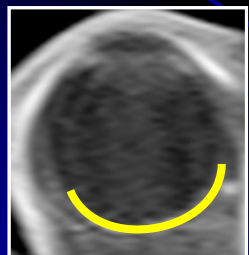
- parallel grooves in the posterior pole



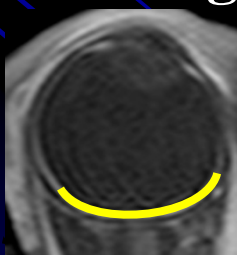
•Optic Disc Edema (swelling)



•Globe Flattening



Normal Globe

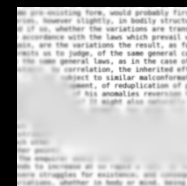


Flatten Globe

MRI Orbital Image showing globe flattening

•Altered Blood flow

•“cotton wool” spots



•Increased Optic Nerve Sheath Diameter

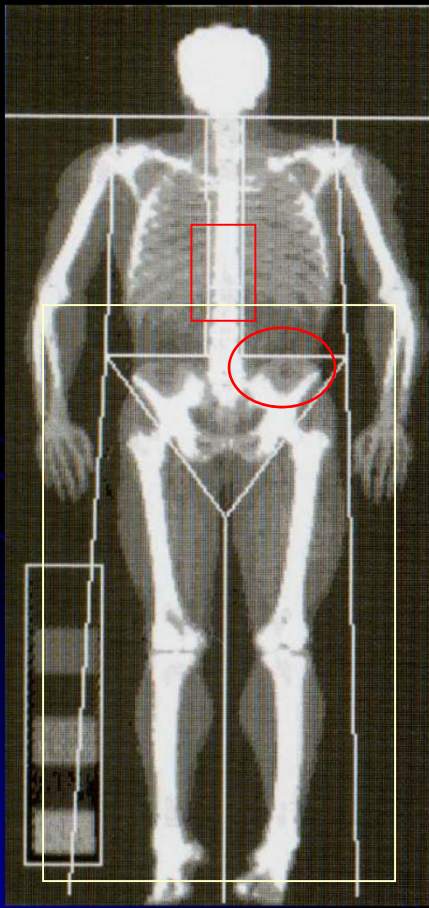


Bone Loss

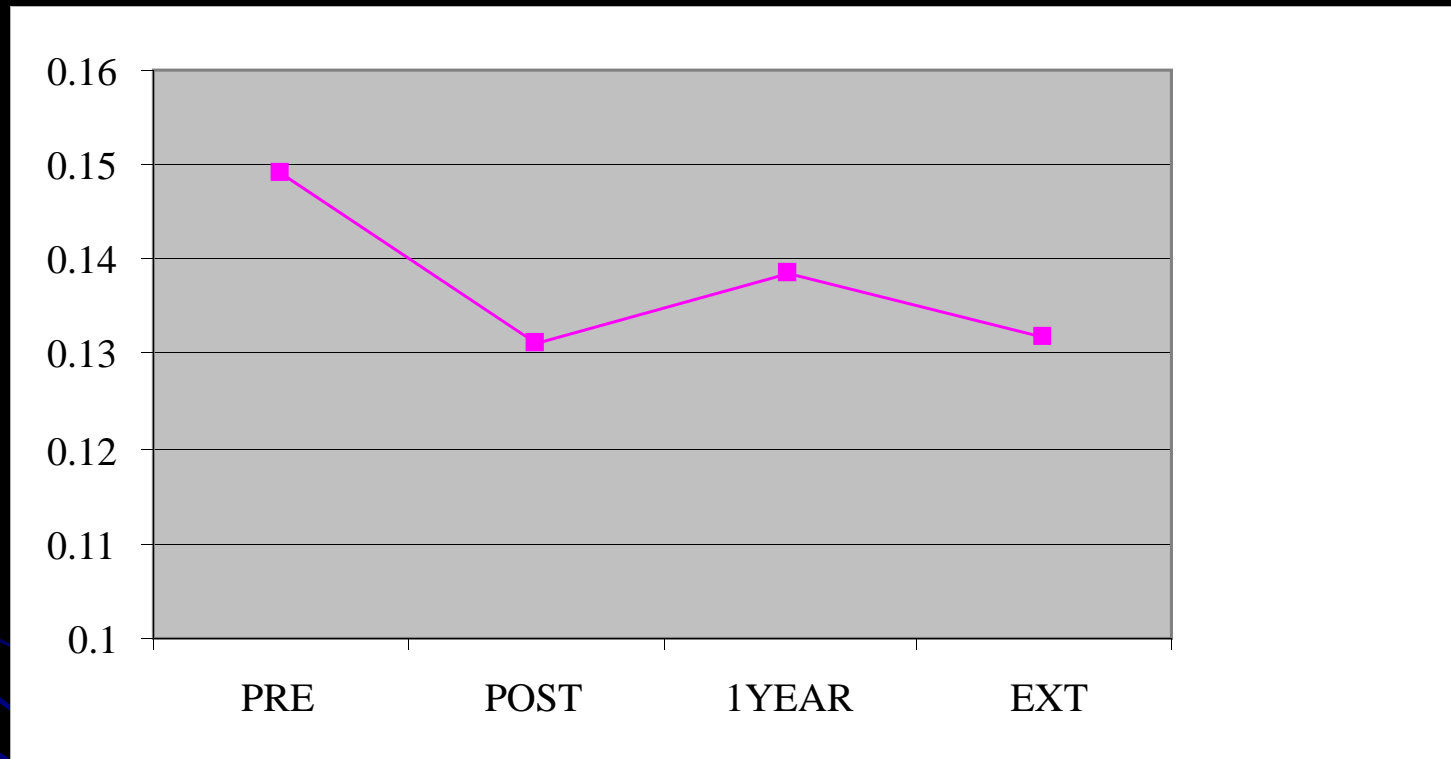


Bone Loss

- Loss of horizontal trabecular



QCT: Trabecular BMD at hip does not appear to show a recovery 2-4 years postflight.



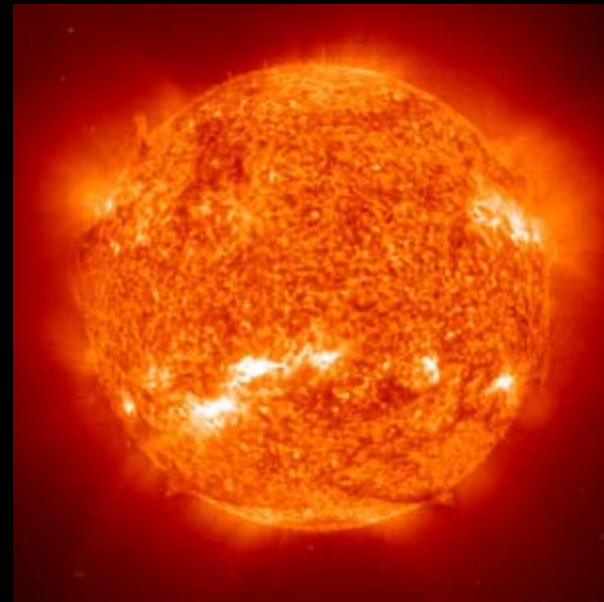
PRE: n= 16 POST: n= 16 1 YEAR: n=16
EXT: n=8

QCT Extension Study (n=8) Postflight Trabecular BMD in hip. Carpenter, D et al. Acta Astronautica, 2010.

Radiation Risk

- Risk Statement

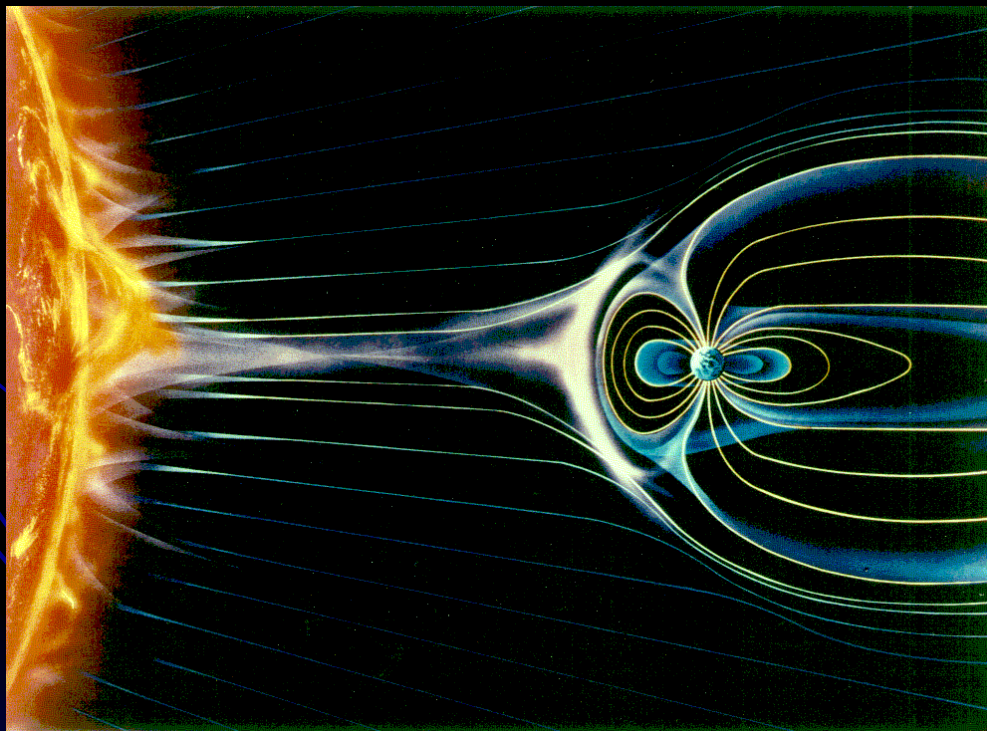
- Given that crewmembers are exposed to radiation from the space environment, there is a possibility for increased cancer morbidity or mortality



Radiation

- Space radiation is a major challenge to exploration:

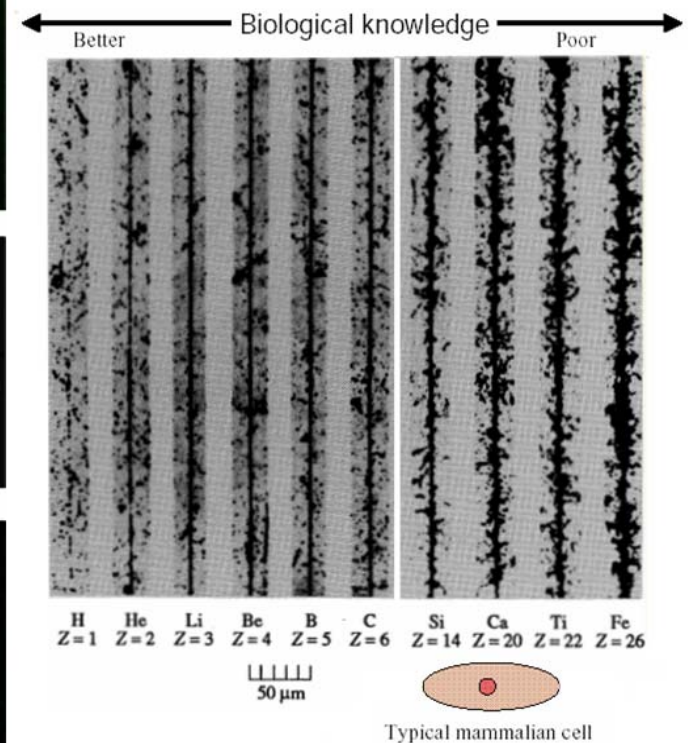
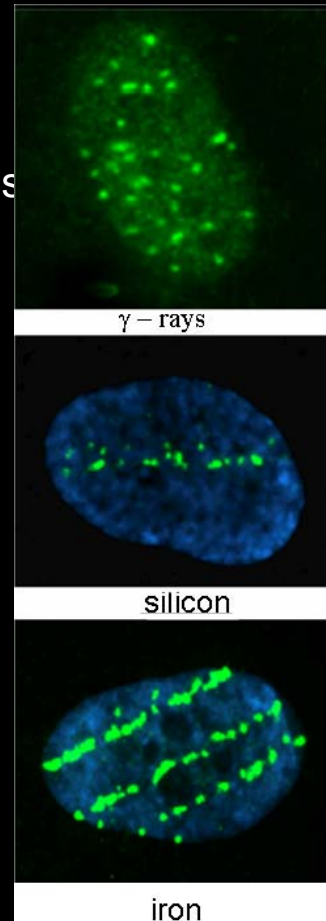
- Risks are high...potentially limiting mission length or crew selection
- Large mission cost and uncertainties to protect against risks
- New findings may change current assumptions



Categories of Radiation Risk

- *Cancer*
- *Acute and Late Central Nervous System (CNS) risks*
 - ✓ Immediate or late functional changes
- *Chronic & Degenerative Tissue Risks*
 - ✓ Cataracts, heart-disease, etc.
- *Acute Radiation Sickness*
 - ✓ Prodromal risks

Differences in biological damage of heavy nuclei in space with x-rays, limits Earth-based data on health effects of heavy ions



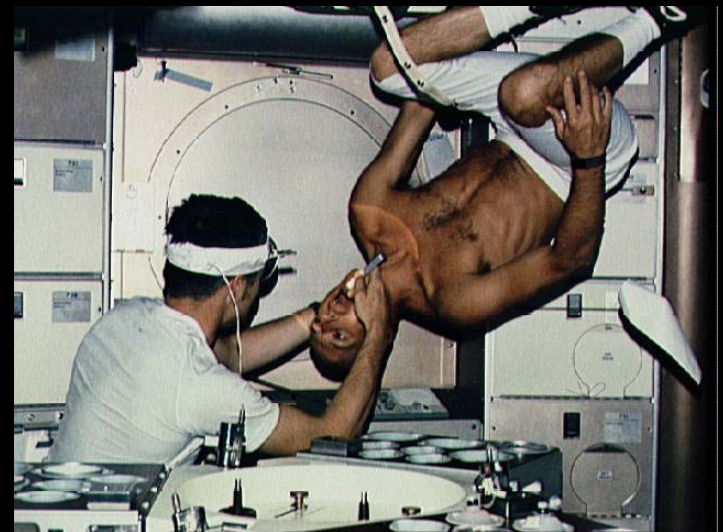
Doctors versus Engineers

- Are humans the reason for the space program, or an inconvenience to the program or both?



Human Systems Integration: The Health Care Professional's Perspective

- Language Gap
- The importance of Human Systems Integration is a lesson that gets relearned over and over again
- Health professionals and engineers speak different technical languages
- Consistent HSI success occurs when health professionals understand and correctly communicate with engineers using “requirements”



Human Factors

- Results:

- Tough lessons relearned
 - Frequently noted in mishap reports
- Human factors being considered after the hardware was developed
 - Past aircraft and today's spacecraft have similar HSI shortcomings
 - Gender issue - average height of women less than average height of men



When does Chronic Stress equal pathology?

More than the individual can cope with.

Fight or flight response degrades physical health.

- Endocrine
- Cardio-vascular
- Digestive
- Neurological
- Cognitive
- Emotional

The longer the degradation, the greater the damage

Humans Stress Humans

Ancient Rome

Cold War Soviet Union

United States at Guantanamo Bay



Case Studies in Stress

Case I: Daily immersion in ice water, forced marches to the point of physical collapse, sleep deprivation, food deprivation, constant yelling and physical intimidation by groups of individuals with weapons.

Case II: Forced to live for 240 continuous hours with constant exposure to 80 decibels. Radiation exposure, muscle wasting, bone damage.

Case III: Restricted primarily to indoor activity, sleep reduction and circadian shifting, indoctrinations and training 12-14 hours a day.

Constant daily, weekly, monthly critical feedback to redirect cognitive, social and emotional processes.

Humans Stress Humans

Training to be a Navy Seal

Being an Astronaut aboard the International Space Station

- Going to Medical School or getting a Ph.D.

When does Chronic Stress not equal pathology?

When the individual can cope.

Physical and mental health improves with challenge.

- Cognitive
- Emotional
- Cardio-vascular
- Digestive
- Endocrine
- Neurological

The longer the challenge, the more likely to reach optimum performance

Chronic Stress as an Asset

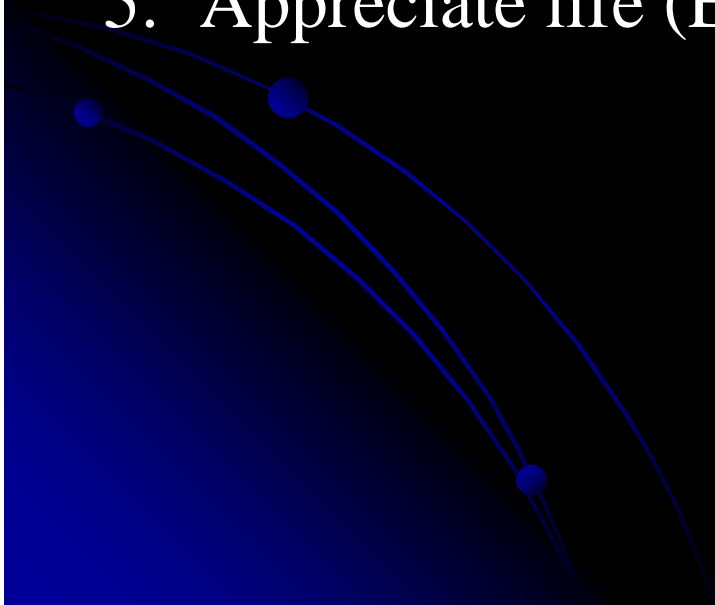
Energy channeled for improvement.

1. Eliminate the 4 F club: Flight, Fight, Freeze or Forget
 - a) Educate the individual about possible stressors to reduce the element of surprise
 - b) Develop coping skills to deal with surprise
2. Work with individuals to develop goals
3. Inform and if possible include the individual in planning exposure(s) to stress(ors)
4. Develop a system of support for the individual to cope with stress(ors)
5. Allow stress at a rate that is healthy for the individual
6. Develop a feedback mechanism for individual about stress(ors)

Chronic Stress as an Asset

Fully supported systems approach

1. Educate the individual about challenges (Intellectual)
2. Train individuals to meet those challenges (Work)
3. Have a network to support individuals (Social)
4. Engage in physical activity (Physical Health)
5. Appreciate life (Emotional or Spiritual Health)



Chronic Stress as an Asset

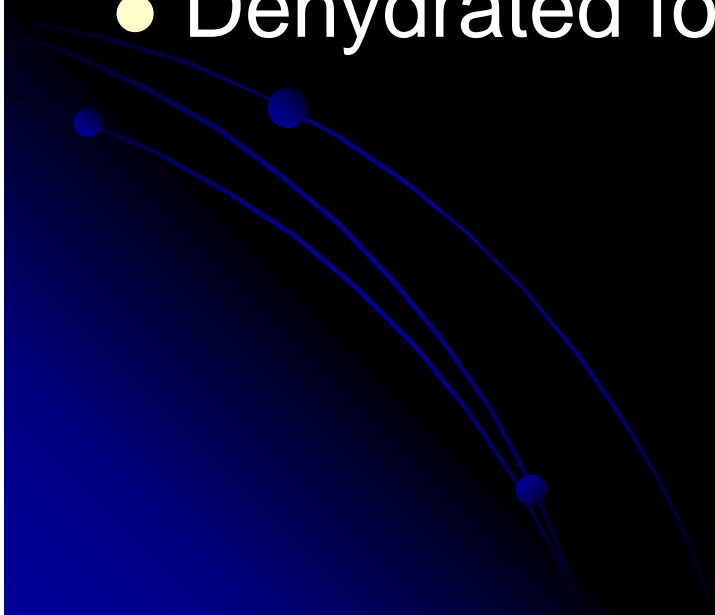
Framing/perspective is key.

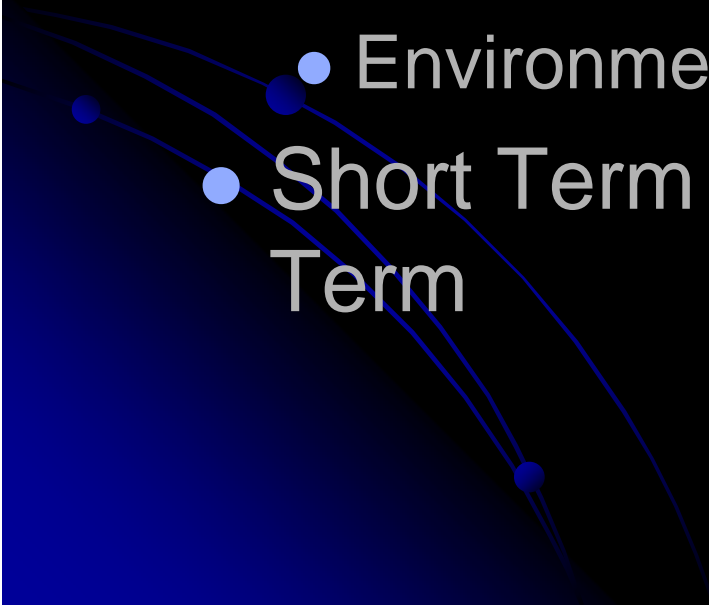
Isolation and confinement as a hero or in support of a good or noble cause has different results than isolation and confinement as a pariah or in support of a bad or evil cause.

Astronaut, Chilean Miner, Licensed Therapist
Psychotic Mass Murder, Terrorist, Sex Trade Worker

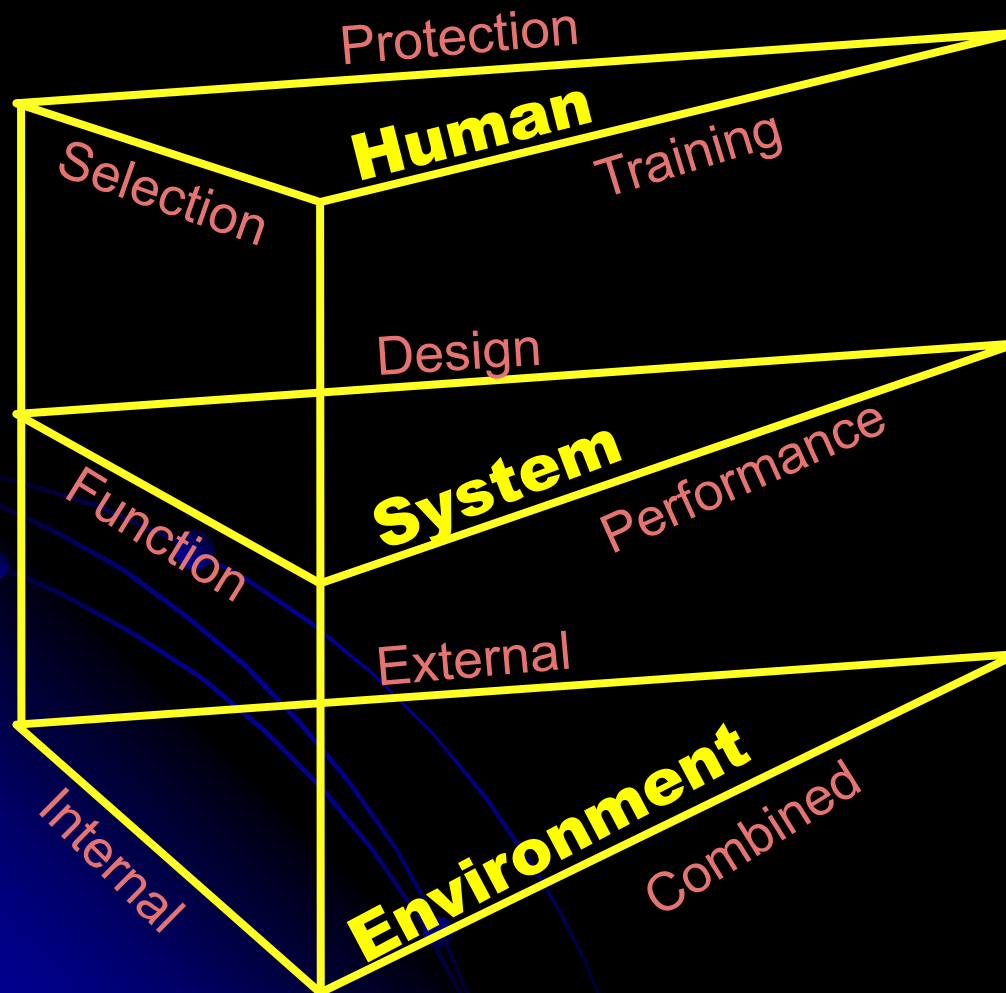
Space Technologies

- Wireless Devices
 - Hospital Telemetry Systems
- Infrared Thermometers
- Cordless Tools
- Dehydrated food...and ice cream too.



- Medical Challenges to Human Space flight
 - Planning for human space missions, a three pronged approach
 - Human
 - System
 - Environment
 - Short Term Missions versus Long Term
- 

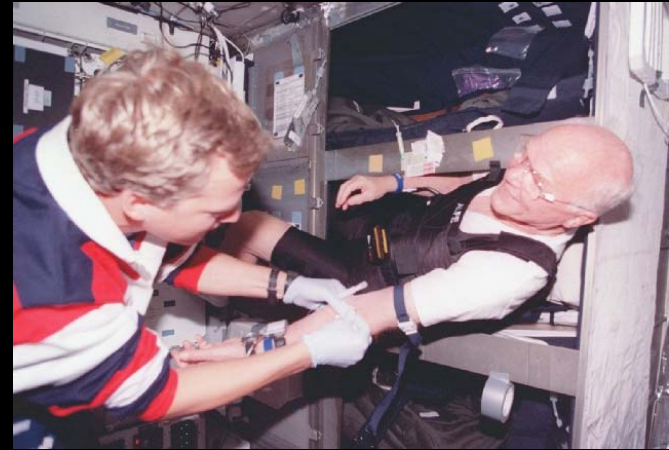
Elements of Human Space Flight



Human
performance is dependent on a...
...System *that responds effectively to...*
...Environmental challenges

Long Duration Mission Health Care Criteria

- Prevent problems
- Treat crew members and return them to duty
- Minimize impact on remainder of crew
- Provide for crew safety
- Provide for remote consultation when possible
- Provide on board resources when possible



Ultimate Health Objective

- Maintain health and well-being before, during, and after mission



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- Dr. Jeff Ayton
- Dr. Iain Grant

Thank You!
Questions?

